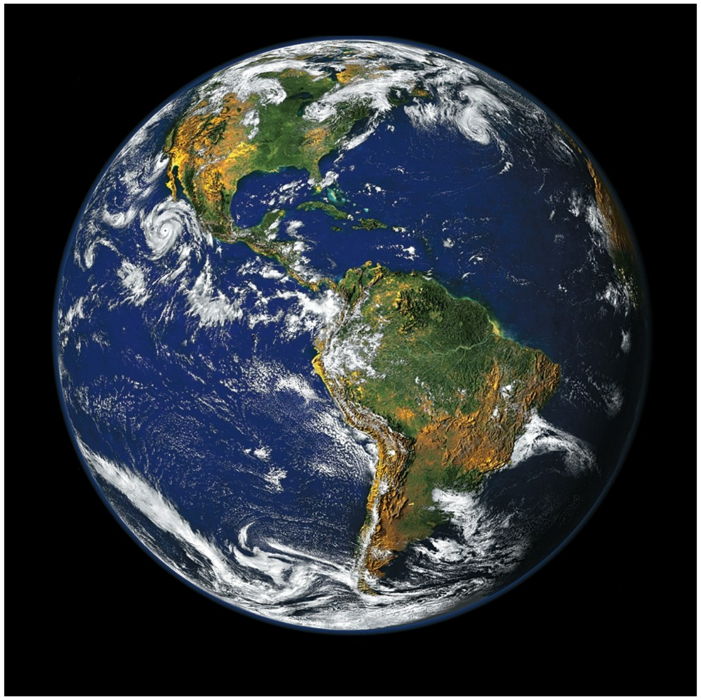


Our Climate: A Global Challenge

Academy for Lifelong Learning

Denver, CO

March 12, 2015

Exponential growth – understand it! Rule of 70 (well, ok, 69.3)

$$N = N_o e^n$$

$$N / N_0 = e^n$$

$$\ln(N / N_o) = n$$; n = 2 for doubling

$$\text{for N} / N_o = 2,\ \ln(2) = 0.693$$

N and n are dimensionless

% are scaled 100x

Rule of 69.3 (100*0.693):
If you have an annual interest rate of r, the time to double your money is 70years/r

e.g. 7% interest, double your money in 10 years

Carrying capacity of our planet

Footprint

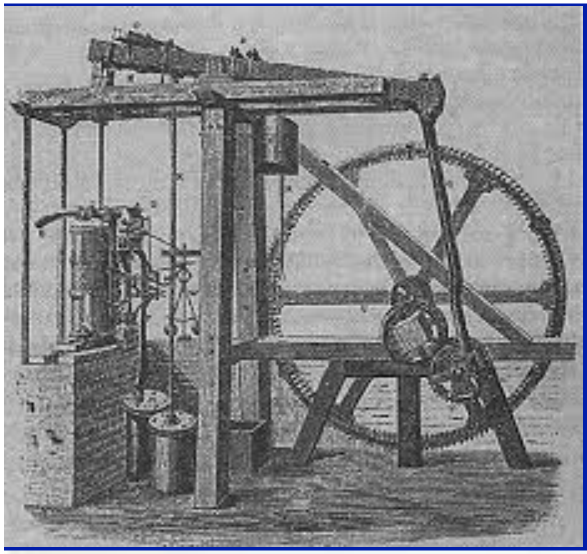
Carrying capacity of our planet

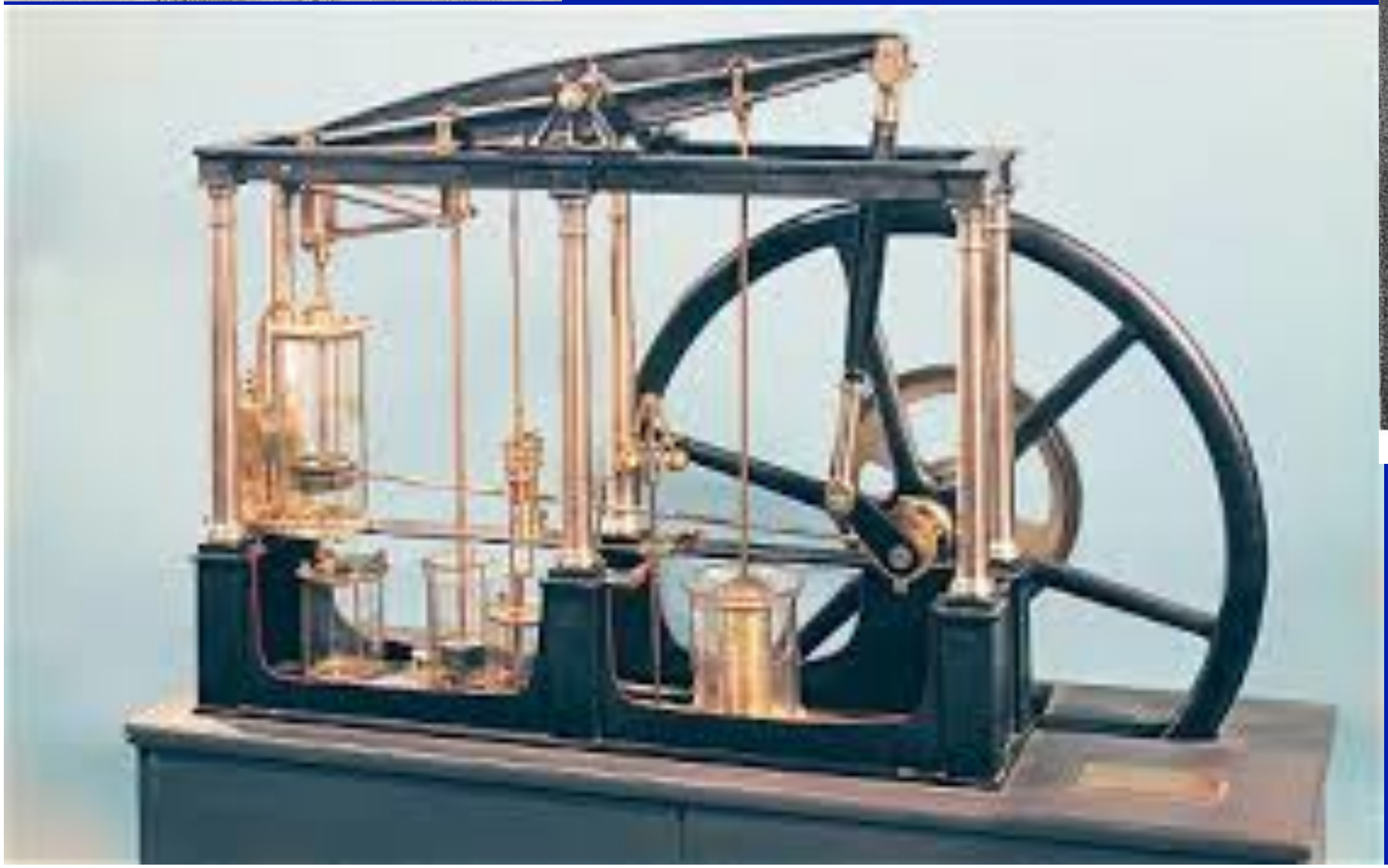
trends and economic cycles

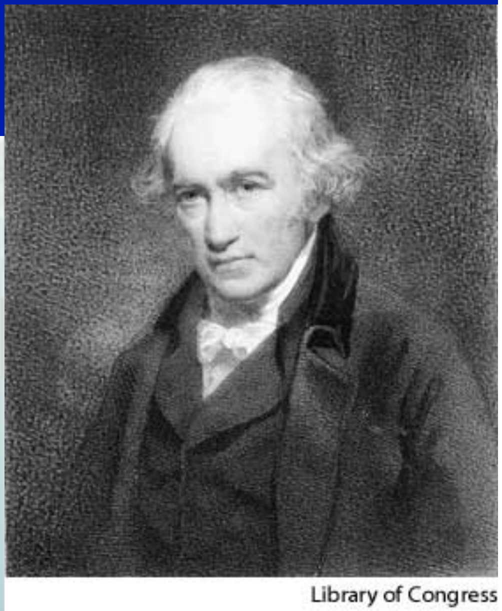
See talk by economist Jeffrey Sachs
at the American Geophysical Union.
Sachs is Director of the Earth Institute at
Columbia University (1 hour long).

https://virtualoptions.agu.org/media/U12B.+Frontier%27s+of+Geophysics+Lecture%2C+Presented+By+Jeffrey++Sachs/0_pf006u0q

Steam engine: economies took off







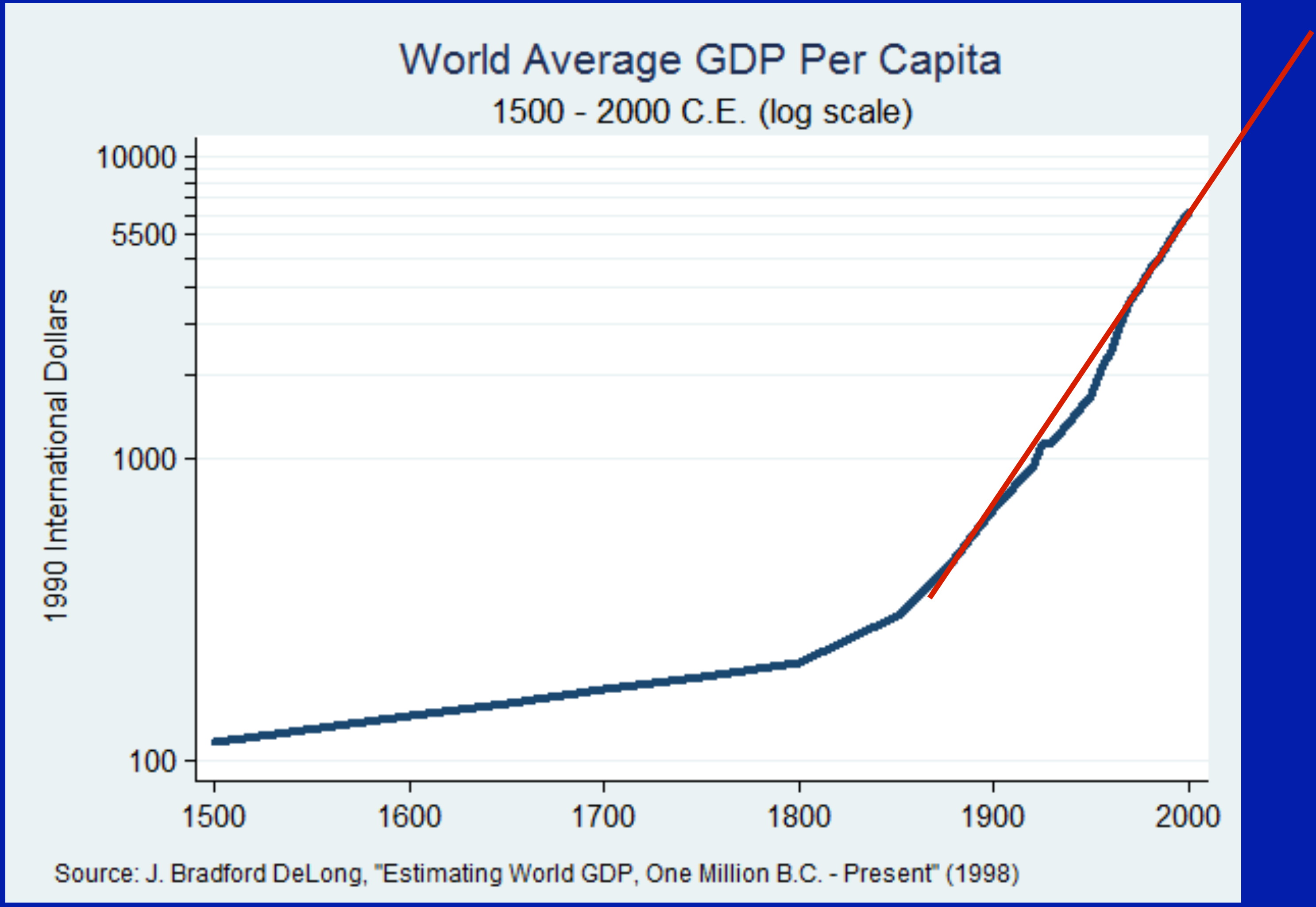
James Watt
(1736-1819)

An amazing period of economic development

- Steam engine
  - James Watt 1781
- Steam+Steel -> Railroads
- Electrification – chemicals
- Auto, airplanes & petrochemicals
- Information technologies, computers

Global economy

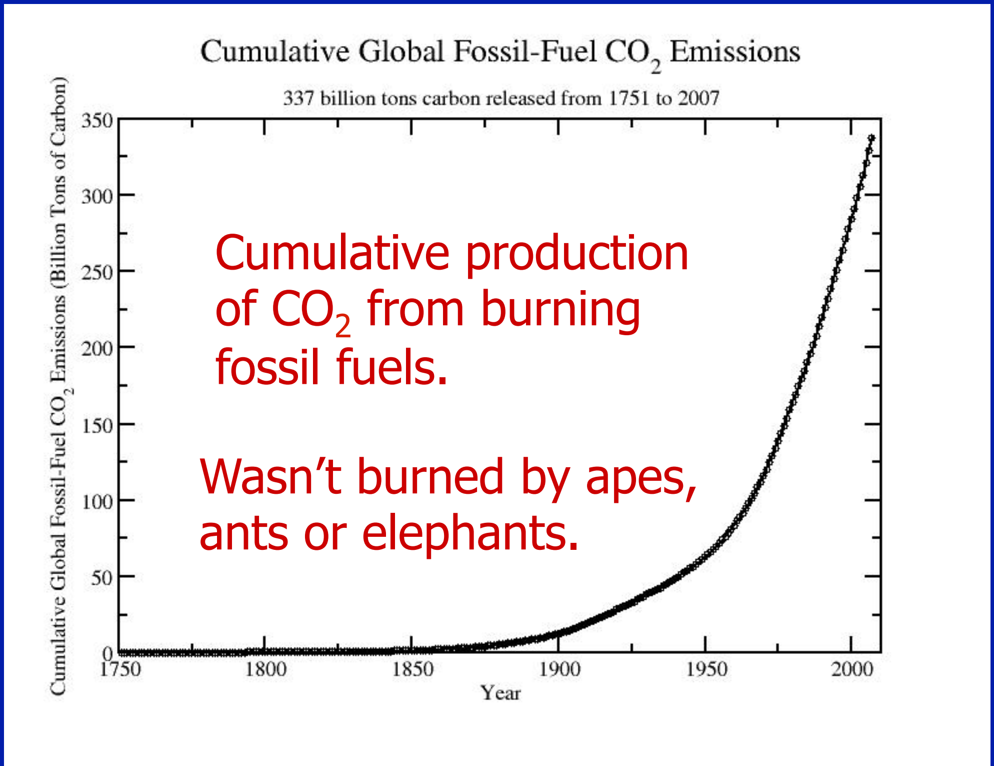
Note log scale, so a straight line is exponential growth.



Changes since 1750

- Population: x 10
- Economic growth: x 100

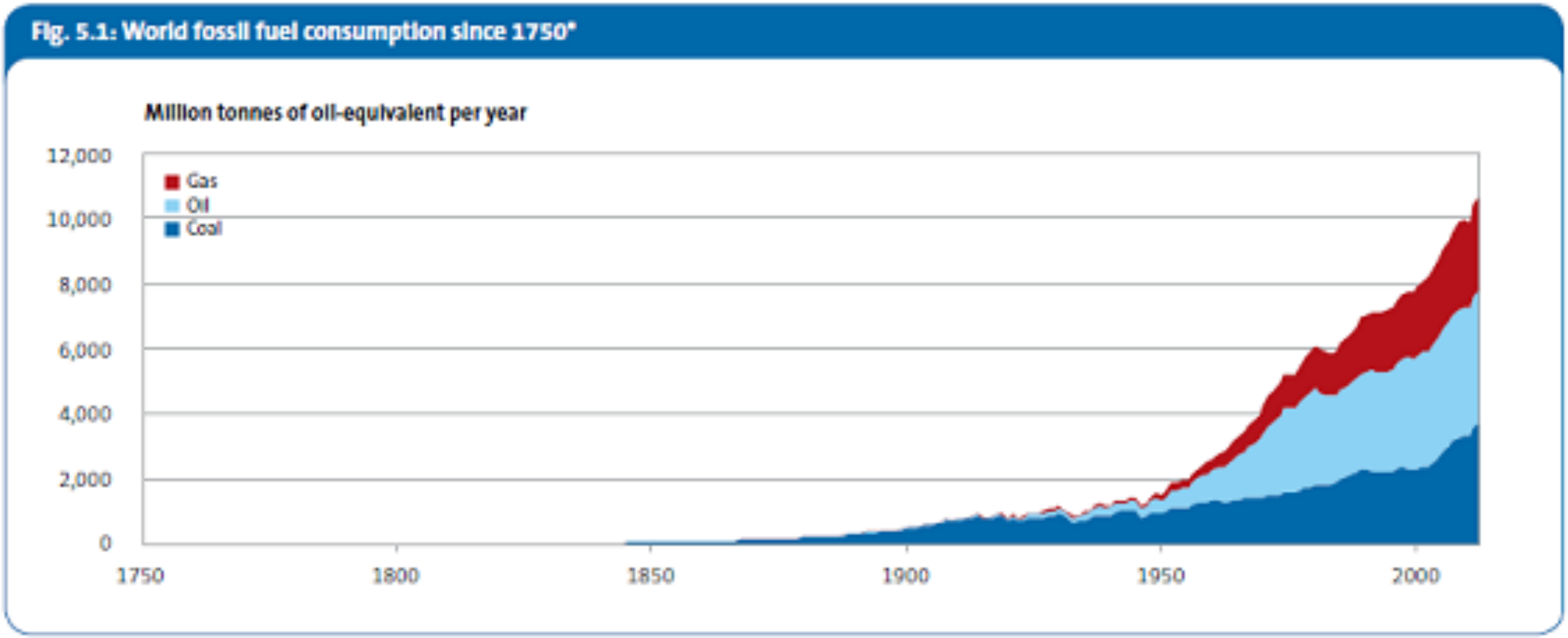
- Economic growth per capita: x 10



Total CO_2 from human activities 2002-2010

- Where has this CO_2 gone?
  - 46% goes into the atmosphere
  - 26% has dissolved in the ocean
  - 28% taken up by plants
- Atmospheric methane: x 3
  - By mass: 20x more potent than CO_2
  - Methane interacts and becomes CO_2 in about 7-15 years, depending on its concentration and the availability of free OH radicals

Fossil fuel consumption history



* Source: Tullett Prebon calculations and estimates from various sources

How many people can the planet support: aka "carrying capacity"

- Depends on lifestyle
  - Estimates vary from 2 to 40 billion
  - 2 B if everyone on Earth lived like a middle-class American, consuming roughly 3.3 times the subsistence level of food and about 250 times the subsistence level of clean water
  - 40 B if everyone on the planet consumed only what he or she needed for subsistence living

People require food: requires water and arable land

Basic survival

- To meet basic human needs, a person could survive for a year on
  - about 100 gallons (400 liters) of water that is not very dirty or salty
  - about 660 pounds (300 kilograms) of food, mostly grain such as rice, or bread
  - a shelter that maintains a temperature above freezing in winter

Daily per capita consumption of energy (footprint)

	Primitive society	Hunting society	Primitive agriculture	Advanced agriculture	Industrial society	Technological society
Food	2	2	4	6	7	10
Home and commerce		3	4	12	32	66
Agriculture and industry			4	7	24	91
Transportation				1	14	63
Total	**2**	**5**	**12**	**26**	**77**	**230**

Global average = 46,000 kilocalories/capita

units 1000 kilocalories: daily consumption requirement to sustain life 2000 kilocalories
(N.b. *calories* on a food package are actually kilocalories; 1000 *calories* = 1 *kilocalorie*)
2000 kilocalories = 100 watts

Adapted from: E. Cook, "The Flow of Energy in an Industrial Society" Scientific American, 1971 p. 135.

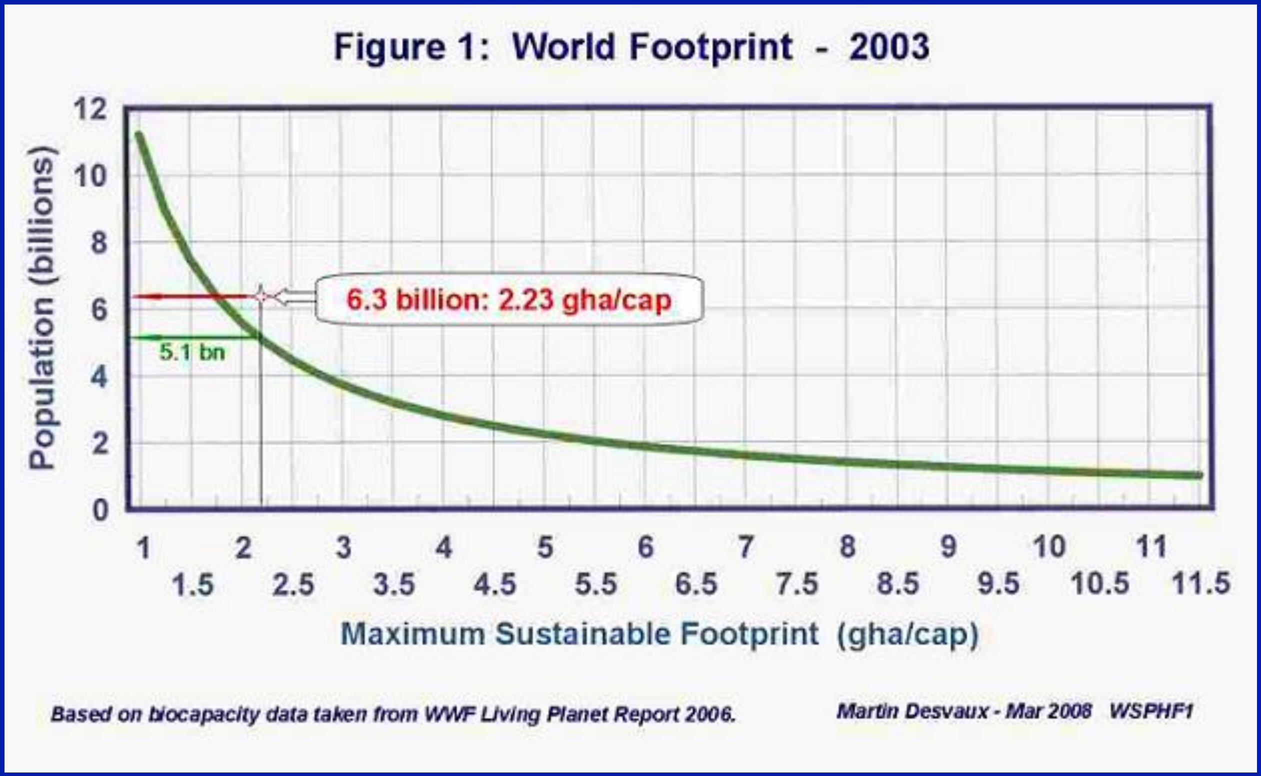
Affluence

The good life! Cars, travel, restaurant food, 2nd homes, fresh fruit from far far away, ...

Per capita consumption of goods and services (GDP/capita); closely related to energy/capita.

This jumped with the start of the industrial revolution and again after WWII. China and India are asking for a lifestyle like ours.

Global footprint = Biocapacity of the earth = 11.2 gha = Maximum per capita footprint × size of sustainable population

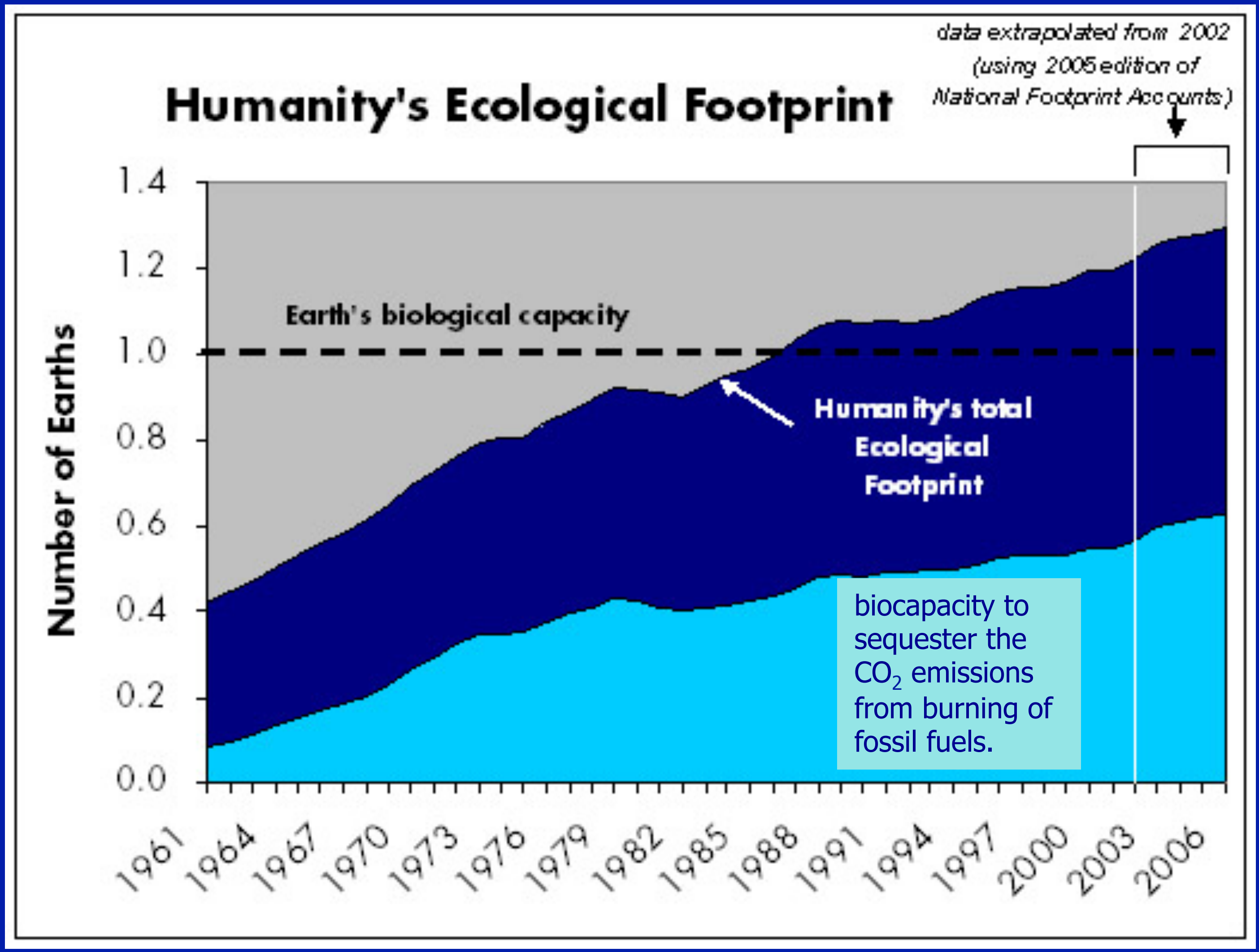


Available:
1.64 gha/cap

Use
Ave: 2.23 gha/cap
USA: 9.4 gha/cap
EU: 4.8 gha/cap
China: 1.6 gha/cap

gha/cap = global hectares per capita: Global total 11.2 gha
http://www.optimumpopulation.org/opt.optimum.html
(1 hectare = 0.405 acres)

In the mid 1980s, humanity began demanding more than the Earth had to give.



http://silencedmajority.blogs.com/silenced_majority_portal/2008/10/global-overshoo.html

Trends that indicate the carrying capacity from the *Earth Policy Institute*

- Population
- Global economy
- Grain harvest
- Fish catch
- Forest cover
- Water resources
- Carbon emissions
- Global temperature
- Ice melting
- Wind and solar power
- Bicycle production

They should have included

- Arable land

Other biota

- Humans currently use about 40% of the terrestrial food supply, leaving only 60% for animals and plants (remember using fish for fertilizer?).
- You might conclude from this that we are at 40% of the carrying capacity. Don't.

Species extinction: loss of habitat and inadequate food supplies

What might break this cycle

- Zero population growth (ZPG)
- Energy without warming
  - no more CO_2
  - wind, solar, hydro, nuclear
- Land and water conservation
- Redefine economy to “no growth” or a “steady state economy”

Non-renewable resources

- If timescale for renewal is greater than the time to consume it is *non-renewable*
  - Some forests might be renewable
  - We are making many fish species non-renewable

- Oil and natural gas
- Coal
- Arable land
  - soil
  - minerals
- Natural aquifers

- Forests
- Fish populations

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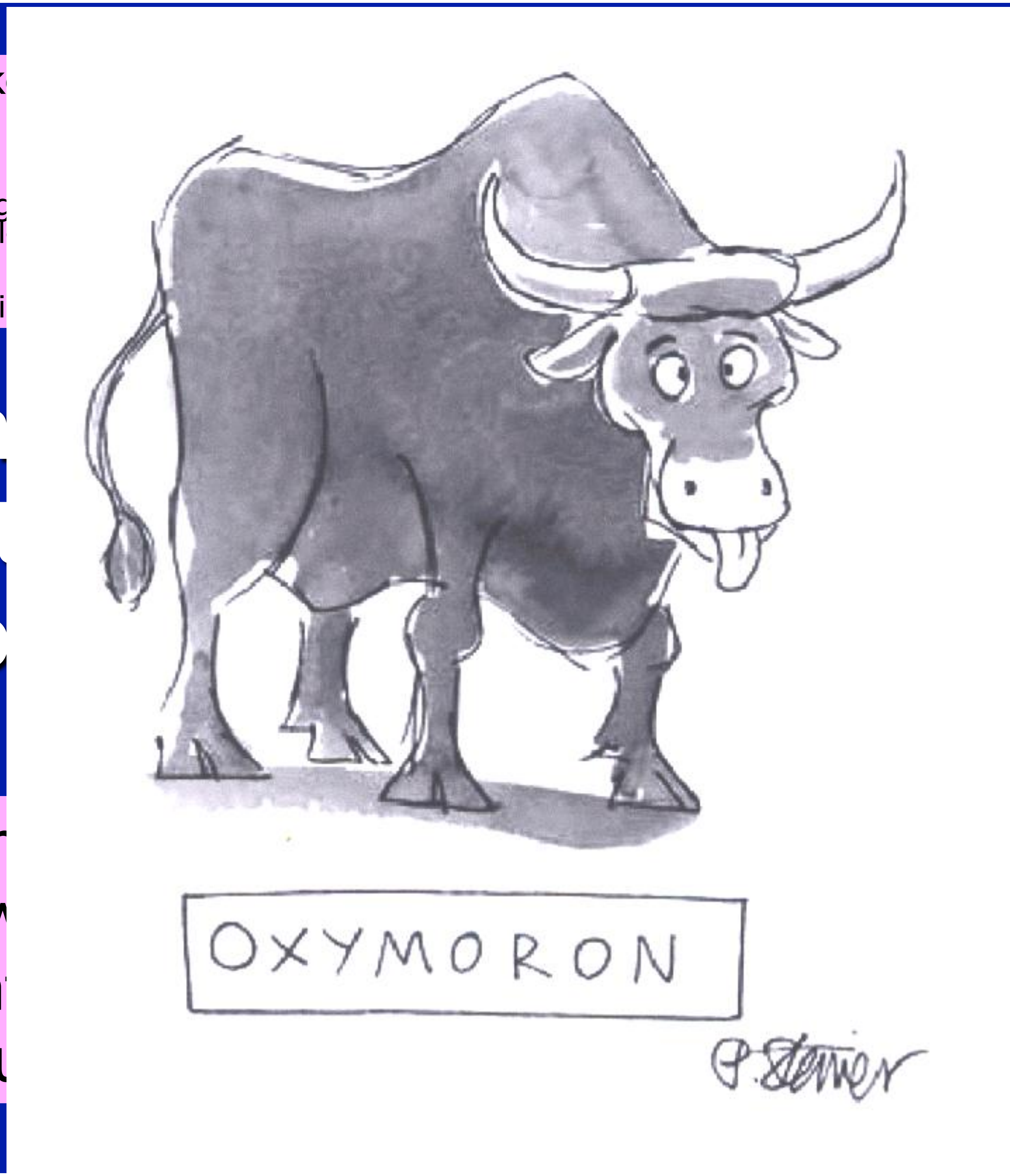

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What values, which is most important?

- Maintain the worth and dignity of every human being
  - How many human beings? What makes life worth living?
- Opportunity
  - Should everyone have the right to our lifestyle?
- Interconnectedness w/ & interdependence on other species
  - Do tigers, snail darters and redwood trees have the same right to existence as we? Is some species more valuable than another?
- Below physical limitations
  - How many people should the Earth support? What quality of life? Who decides?
- The planet will be here until it is destroyed when the sun becomes a red giant star and then finally explodes.
  - Why do we need to “save the planet”? For whom? For how long?
  - Will we adapt and/or evolve naturally? Is it right to try and control the environment? Our own evolution?

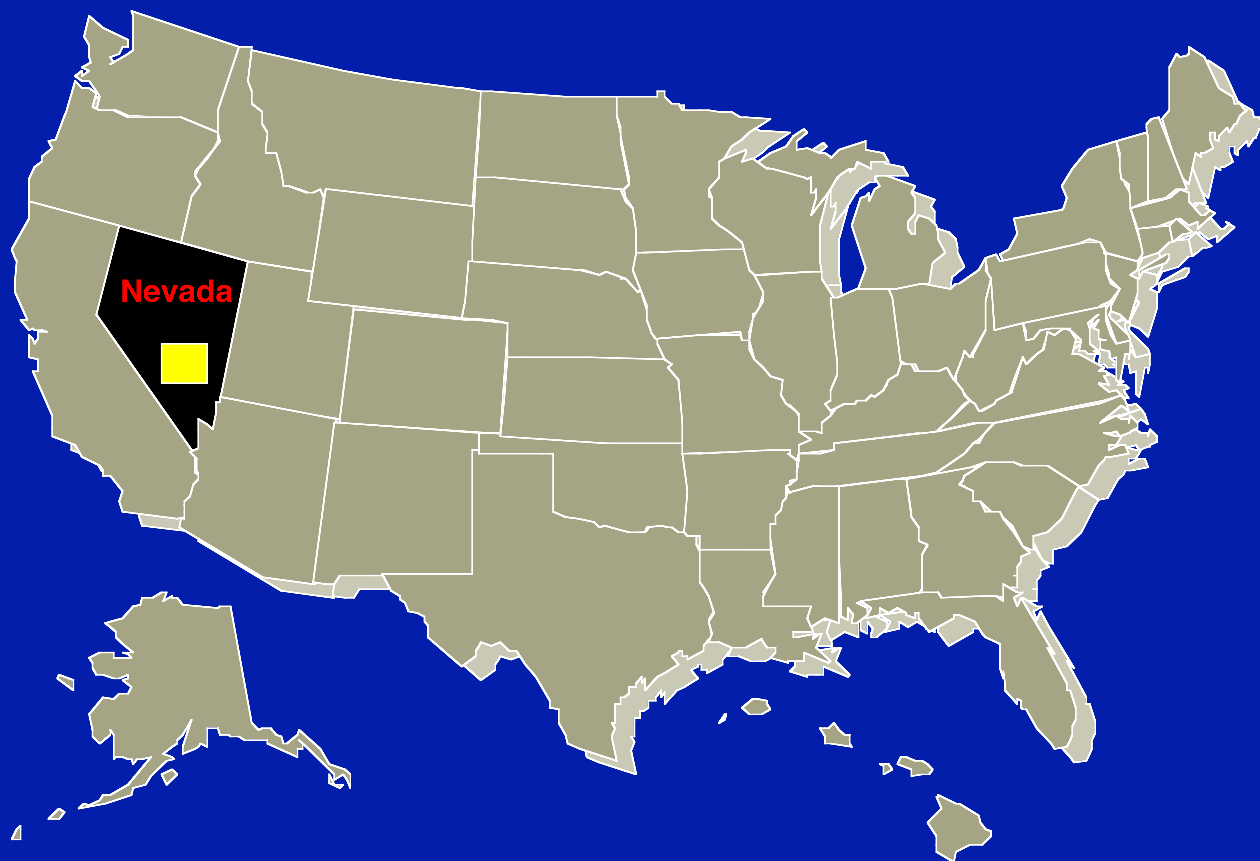
Elements of *near-term* stewardship

- Education and awareness
- Empower women
- Promote birth control
- Graduated tax on consumption (vs. income - savings)
- Solar power (consider nuclear)
- Aim for zero global population growth
  - cap and trade on number of children
  - no net growth
- Global scale planning and actions
- Enforce fishery, land and water conservation
- Support parks, preserves and nature corridors

Success stories: What we need to do has been done before.

- Reforestation in South Korea
- Rooftop solar water heating in China
- Crop residues to protein (but methane)
  - Milk production from in India
  - Beef in China
- Geothermal energy in Iceland
- Wind farms in Denmark
- Soil conservation tillage in the USA (but fertilizer)
- Population stabilization in Eastern Europe, Russia

Total Area Required for a Photovoltaic Power Plant to Produce the Total U.S. Annual Electrical Demand



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J. A. Turner, “A Realizable Renewable Energy Future”, Science, 285, p 5428, (1999).

Summary: climate change is part of a bigger picture of sustainable living

- Accessible water and arable land determine the carrying capacity
- We are arguably using more resources than the planet can provide
- Must "borrow" from the Earth to support additional people temporarily (how long??)
  - finite resources provide limit
- More for us, less for other species